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Low-frequency radio observations of the galaxy cluster CIZA J2242.8+5301

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Abstract. Some disturbed galaxy clusters host diffuse elongated radio sources, also called radio relics. It is proposed that these relics trace shock waves in the intracluster medium (ICM). Within the shock waves, generated by cluster merger events, particles are accelerated to relativistic energies, and in the presence of a magnetic field synchrotron radiation will be emitted. CIZA J2242.8+5301 is a disturbed galaxy cluster hosting complex diffuse radio emission, including a so-called double radio relic. Here we present new Giant Metrewave Radio Telescope (GMRT) radio observations of CIZA J2242.8+5301 at 325 and 150 MHz. We detect the double radio relic at 150 and 325 MHz. The very deep 150 MHz image reveals the presence of large-scale diffuse emission between the two radio relics.

Key words. Radio Continuum: galaxies – Galaxies: active – Clusters: individual : CIZA J2242.8+5301 – Cosmology: large-scale structure of Universe

1. Introduction

Galaxy clusters grow by mergers with other clusters or galaxy groups, as well as through the accretion of gas from the intergalactic medium (IGM). Both these two processes shock the ICM. It has been proposed that within these shocks particles can be accelerated to highly relativistic energies by the diffusive shock acceleration (DSA) mechanism (Krymskii 1977; Axford et al. 1977; Bell 1978a,b; Blandford & Ostriker 1978; Drury 1983; Blandford & Eichler 1987; Jones & Ellison 1991; Malkov & O'C Drury 2001). It is thought that radio relics, elongated steep-spectrum radio sources (e.g., Giovannini et al. 1991; Bagchi et al. 2006; Giacintucci et al. 2008; Brown et al. 2011), trace these shock waves generated by cluster merger events (Ensslin et al. 1998; Miniati et al. 2001).

CIZA J2242.8+5301 is a disturbed galaxy cluster located at $z = 0.1921$ (Kocevski et al. 2007). The cluster hosts a large double radio relic system, as well as additional large-scale diffuse radio emission (van Weeren et al. 2010). The spectral index (α) across the bright northern relic steepens systematically in the direction of the cluster center, across the

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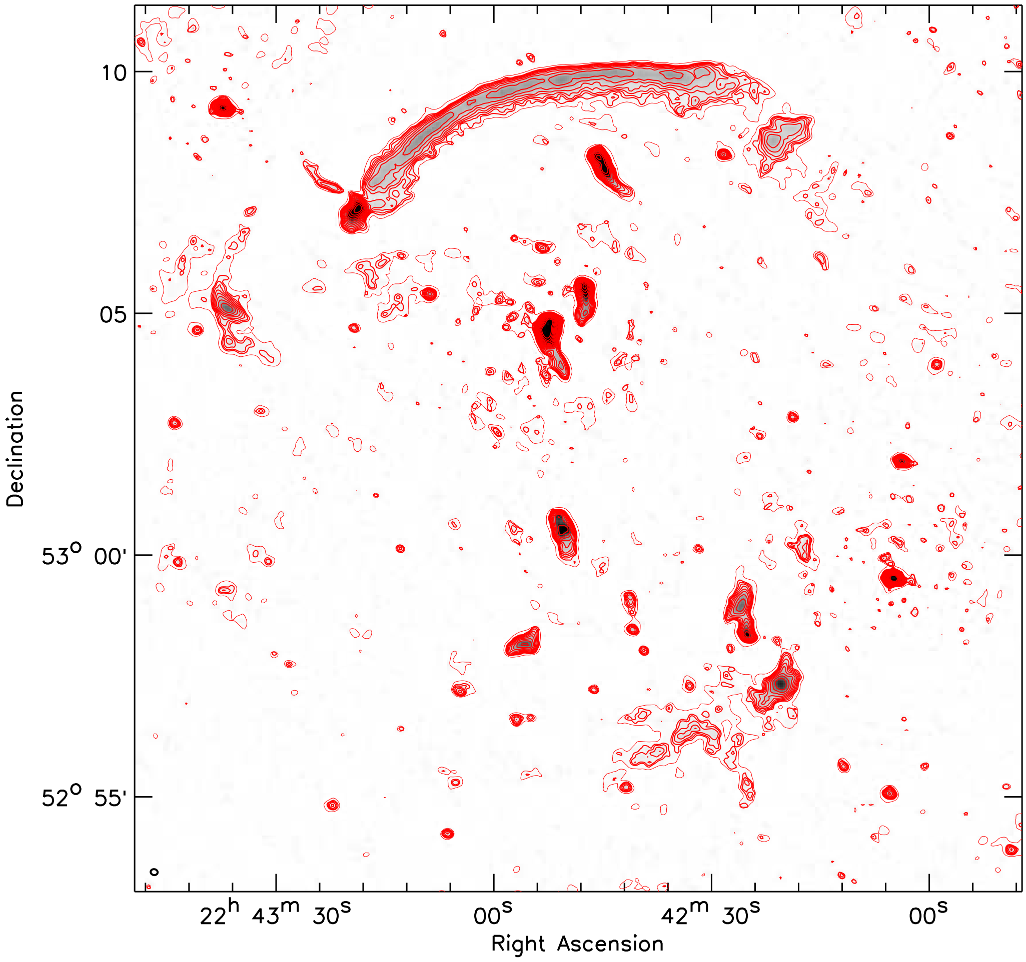

Fig. 1. GMRT 325 MHz image made with robust weighting set to −1.0 (Briggs 1995). The image has a rms noise of 59 μJy beam^{-1}. Contour levels are drawn at $\sqrt{[1, 2, 4, 8, \ldots]} \times 4\sigma_{\rm rms}$. The beam size is $8.7'' \times 7.4''$ and shown in the bottom left corner of the image. A thinner contour from an image with robust weighting set to 0.5, with a resolution of $11.5'' \times 9.8''$, is drawn at a level of 0.2 mJy beam^{-1}.

full length of the narrow relic. This is expected for outwards moving shock waves, with synchrotron and inverse Compton losses behind the shock front. Here we present new low-frequency GMRT radio images at 150 and 325 MHz, which complement our previous higher frequency observations at 610 and 1400 MHz (van Weeren et al. 2010).

2. Observations

We carried out radio observations with the GMRT of CIZA J2242.8+5301 at 150 and 325 MHz. The total bandwidth was 6 and 32 MHz at 150 and 325 MHz, respectively. The 325 MHz data were reduced in a standard way using the NRAO Astronomical Image Processing System (AIPS) package. A few bright sources were removed using the "peeling" scheme (e.g., Noordam 2004). The data were affected by strong radio frequency inter-

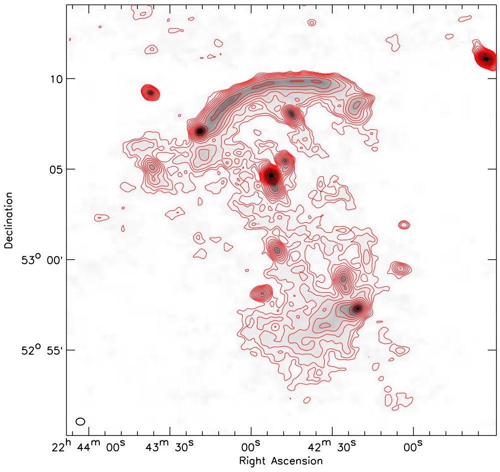

Fig. 2. GMRT 150 MHz image. The image has a rms noise of 1.0 mJy beam^{-1}, and the resolution is 30″ × 24″. Contour levels are drawn at $\sqrt{[1, 2, 4, 8, \ldots]} \times 4\sigma_{\rm rms}$.

ference (RFI), preventing the use of the shortest baselines.

For the 150 MHz data the ionospheric calibration scheme from Intema et al. (2009) was employed. In addition, RFI was fitted and subtracted from the data using the technique described by Athreya (2009) which was implemented in Obit (Cotton 2008).

For both datasets we used the polyhedron method (Perley 1989; Cornwell & Perley 1992) for making the images to minimize the effects of non-coplanar baselines.

3. Results

The 325 MHz image displays both the northern and southern relic. At 325 MHz we also detect a patch of diffuse emission located just south of the bright tailed-radio source at the eastern end of the northern giant relic. In addition, the diffuse source to the southeast of the tailed radio source is detected. These sources could be radio relics tracing additional shock structures. The 325 MHz image reveals none of the large-scale diffuse emission between the southern and northern giant relics, which was previously found in a deep Westerbork Synthesis Radio Telescope (WSRT) 1.4 GHz image (van Weeren et al. 2010). We attribute this to the fact that most of the short baseline had to be "flagged" because of RFI. At 150 MHz we detect the large-scale diffuse component between the northern and southern relics, confirming its existence. Interestingly, the width of the northern relic is much wider than in our 1.4 GHz WSRT map, consistent with a very steep spectral index ($\alpha \lesssim -2$) in the region at the back of the shock due to synchrotron losses having severely reduced the emission at higher frequencies.

4. Conclusions

We detect both the northern and southern radio relics in the galaxy cluster CIZA J2242.8+5301 with the GMRT at 150 and 325 MHz . The 150 MHz image reveals the presence of additional diffuse emission throughout the cluster with a total extent of about 3 Mpc, confirming the results from our a previous WSRT 1.4 GHz observation. In a future paper we will present a more detailed spectral analysis of the radio emission in the cluster.

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References

Athreya, R. 2009, ApJ, 696, 885
Axford, W. I., Leer, E., & Skadron, G. 1977, in International Cosmic Ray Conference, Vol. 11, International Cosmic Ray Conference, 132–+
Bagchi, J., Durret, F., Neto, G. B. L., & Paul, S. 2006, Science, 314, 791

Bell, A. R. 1978a, MNRAS, 182, 147
Bell, A. R. 1978b, MNRAS, 182, 443
Blandford, R. & Eichler, D. 1987, Phys. Rep., 154, 1
Blandford, R. D. & Ostriker, J. P. 1978, ApJ, 221, L29
Briggs, D. S. 1995, PhD thesis, New Mexico Institute of Mining Technology, Socorro, New Mexico, USA
Brown, S., Duesterhoeft, J., & Rudnick, L. 2011, ApJ, 727, L25+
Cornwell, T. J. & Perley, R. A. 1992, A&A, 261, 353
Cotton, W. D. 2008, PASP, 120, 439
Drury, L. O. 1983, Reports on Progress in Physics, 46, 973
Ensslin, T. A., Biermann, P. L., Klein, U., & Kohle, S. 1998, A&A, 332, 395
Giacintucci, S., Venturi, T., Macario, G., et al. 2008, A&A, 486, 347
Giovannini, G., Feretti, L., & Stanghellini, C. 1991, A&A, 252, 528
Intema, H. T., van der Tol, S., Cotton, W. D., et al. 2009, A&A, 501, 1185
Jones, F. C. & Ellison, D. C. 1991, Space Science Reviews, 58, 259
Kocevski, D. D., Ebeling, H., Mullis, C. R., & Tully, R. B. 2007, ApJ, 662, 224
Krymskii, G. F. 1977, Akademiia Nauk SSSR Doklady, 234, 1306
Malkov, M. A. & O'C Drury, L. 2001, Reports on Progress in Physics, 64, 429
Miniati, F., Jones, T. W., Kang, H., & Ryu, D. 2001, ApJ, 562, 233
Noordam, J. E. 2004, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 5489, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, ed. J. M. Oschmann, Jr., 817–825
Perley, R. A. 1989, in Astronomical Society of the Pacific Conference Series, Vol. 6, Synthesis Imaging in Radio Astronomy, ed. R. A. Perley, F. R. Schwab, & A. H. Bridle, 259–+
van Weeren, R. J., Röttgering, H. J. A., Brüggen, M., & Hoeft, M. 2010, Science, 330, 347